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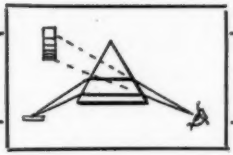


JANUARY
1932

PROCEEDINGS
of the

Sixteenth Annual Meeting

ROCHESTER, N. Y.

October 22–24, 1931

MINUTES OF THE MEETING

The sixteenth annual meeting of the Optical Society of America was held at Rochester, New York, October 22–24, 1931.

The meeting convened Thursday morning at the Hotel Sagamore. The meeting was opened by F. K. Richtmyer introducing President L. A. Jones, who welcomed the Society on behalf of the Rochester members.

President Jones recalled that the Society had been organized in Rochester in 1916 and that it had been just ten years since the Society had held its annual meeting in Rochester. Professor Richtmyer replied on behalf of the Society and then relinquished the chair to the President.

DINNER AT BAUSCH AND LOMB PLANT AND EXHIBIT OF INSTRUMENTS

The members of the Society and guests were entertained Thursday evening by the Bausch and Lomb Optical Company at their factory with a complimentary dinner. Following the dinner Mr. Jones introduced Mr. Edward Bausch, President of the Bausch and Lomb Optical Company and one of the charter members of the Society. Mr. Bausch

extended to the Society a welcome from the Bausch and Lomb Company following which they were entertained by moving pictures illustrating the principles and manufacture of optical instruments. This was followed by an exhibit of the newer models of instruments manufactured by the company.

SESSION DEVOTED TO SOME OPTICAL PROBLEMS OF THE MOTION PICTURE INDUSTRY

The sessions Friday were held in the Kodak Research Laboratory auditorium. After a welcome by Dr. C. E. K. Mees, the morning was devoted to papers on some optical problems of the motion picture industry. The following papers were presented by invitation:

The Optical Problems Involved in the Recording and Reproducing of Sound on Film, by A. C Hardy, Massachusetts Institute of Technology.

Optical Problems Involved in Photographing and Projecting Motion Pictures, by W. B. Rayton, Bausch and Lomb Optical Company.

The Problems of Motion Picture Projection from Continuously Moving Film, by F. E. Tuttle and C. D. Reid, Eastman Kodak Company.

LUNCH AT KODAK PARK AND INSPECTION OF THE KODAK RESEARCH LABORATORY

At luncheon Friday the members of the Society and their guests were guests of the Eastman Kodak Company, and the early part of the afternoon was spent in inspecting the Kodak Research Laboratories.

TRIBUTE TO A. A. MICHELSON AND S. W. STRATTON

Before taking up the program of contributed papers Friday afternoon the Society paused to pay a tribute to the members it had lost during the year. On request of the President, the secretary read the names of members who had died. Among them were two of the honorary members of the Society—A. A. Michelson and S. W. Stratton. At the request of the President, Professor Edward L. Nichols gave a brief tribute to the contributions of these two to science and in particular to the science of optics, calling attention to the different ways in which the two men so differently gifted had each played his part.

AWARD OF FREDERIC IVES MEDAL TO PROFESSOR THEODORE LYMAN

The annual dinner at the Hotel Sagamore Friday evening, October 23, was held in honor of Professor Lyman who had been awarded the Frederic Ives Medal for 1931. To the regret of all, illness prevented Professor Lyman from attending the meeting.

C. E. K. Mees of the committee on the award of the Frederic Ives Medal announced the award and the decision of the Council that in

view of Professor Lyman's illness the formal presentation would be postponed until the February meeting.

AMERICAN INSTITUTE OF PHYSICS

Dr. Henry A. Barton, Director of the newly organized American Institute of Physics, outlined the tentative plans of the Institute so far as they had been formulated.

WELCOME BY UNIVERSITY OF ROCHESTER

Dr. Rush Rhees, President of the University of Rochester, extended to the members of the Society a welcome from the University of Rochester, in particular from its Institute of Optics.

VISIT TO THE NEW RIVER CAMPUS OF THE UNIVERSITY OF ROCHESTER

Following the dinner the members of the Society had an opportunity to inspect the laboratories of the Institute of Optics at the New River Campus of the University of Rochester.

The Sessions Saturday morning were held in the Physics Laboratory of the University of Rochester.

BUSINESS SESSION

A brief business session of the Optical Society was held Saturday morning, October 24, President Jones presiding.

Informal reports of the secretary, the treasurer and the business manager of the journal were presented. (Note: The Society's fiscal year being identical with the civil calendar year, the officers' formal reports are made as of December 31, each year and published in the journal).

In his report the secretary called attention to the fact that in spite of the business depression, the membership in the Society continued to increase.

The treasurer noted that the finances of the Society were in good condition.

The secretary presented the report of the tellers on the election of officers

For the term beginning January 1, 1932 and ending December 31, 1933:

President, E. C. Crittenden.
Vice-President, W. B. Rayton.
Members of Council:

A. C. Hardy	T. R. Wilkins
G. S. Fulcher	A. G. Worthing

For the term beginning January 1, 1932 and ending December 31, 1936:

Treasurer, Adolph Lomb.

These officers were declared elected.

VOTE OF THANKS TO THE BAUSCH AND LOMB OPTICAL COMPANY, EASTMAN KODAK COMPANY, THE UNIVERSITY OF ROCHESTER, ROCHESTER SECTION OF THE OPTICAL SOCIETY AND THE LOCAL COMITTEE

On motion the Society unanimously directed the Secretary to write letters of thanks to the Bausch and Lomb Optical Company, The Eastman Kodak Company, the University of Rochester, the Rochester Section of the Optical Society and the local committee for their hospitality and many courtesies which had contributed to a highly successful and enjoyable meeting.

There being no other business, the business session was adjourned, and the reading of invited papers taken up.

SESSIONS DEVOTED TO AERIAL PHOTOGRAPHIC MAPPING

The sessions Saturday morning and afternoon were devoted to invited papers on aerial photographic mapping. The following papers were presented by invitation:

The Optical Requirements of Airplane Mapping, by I. C. Gardner, Bureau of Standards.

Analytical Methods in Aerial Photogrammetry, by Earl Church, L. C. Smith College of Applied Science.

Photographic Mapping Instruments and Methods, by C. H. Birdseye, Aerotopograph Corporation.

Developments in Aerial Photography, by A. W. Stevens, Air Corps, U. S. Army.

The Brock Aerial Mapping Process, by E. H. Cahill, Brock and Weymouth, Inc.

Preparation of Relief Maps from Aeroplane Photographs, by H. L. Cooke, Princeton University.

ATTENDANCE

The total registration was:

Members	94
Guests	51
Total	145

The attendance at the several sessions was approximately as follows:

Thursday, October 22, 9:00 A.M.	80
Thursday, October 22, 2:00 P.M.	100
Thursday, October 22, 6:30 P.M.	150
Friday, October 23, 9:00 A.M.	140
Friday, October 23, 2:00 P.M.	100
Saturday, October 24, 9:00 A.M.	100
Saturday, October 24, 2:00 P.M.	90

One hundred and ten persons attended the dinner in honor of Professor Theodore Lyman.

SESSIONS FOR THE READING AND DISCUSSION OF CONTRIBUTED PAPERS

Sessions for the reading and discussion of contributed papers were held as follows:

October 22, 9:15 A.M. Photometry and Colorimetry.
October 22, 2:00 P.M. Optical Instruments, and Physical and Chemical Optics.
October 23, 3:00 P.M. Photography.

At the session Thursday afternoon the secretary presented a paper contributed by Armand de Gramont, President of the Institut d' Optique of Paris, France. M. de Gramont had been unable to accept the invitation of President Jones, to attend the meeting at Rochester, but had contributed this paper.

The authors' abstracts of these papers are appended.

MEETINGS OF THE COUNCIL

Meetings of the executive council were held as follows:

Wednesday, October 21, 2:30 P.M.

Wednesday, October 21, 7:30 P.M.

(*Signed*) L. B. TUCKERMAN, *Secretary*

MINUTES OF THE EXECUTIVE COUNCIL

Annual Meeting at Rochester, N. Y., October 22–24, 1931.

Beside the transaction of routine business the following items of general interest to the members of the Society were taken up.

1. The President reported the organization of the Inter-Society Color Council with Professor E. N. Gathercoal as Permanent Chairman; M. Rea Paul as Permanent Secretary, and A. E. O. Munsell as Permanent Treasurer.

At the organization meeting of the Inter-Society Color Council approximately thirty representatives of approximately fifteen organizations were present and the second meeting was planned to be called in December to perfect the organization.

2. The Council accepted the report of the Committee on the award of the Frederic Ives Medal, but decided that in view of the illness of Professor Lyman, formal presentation of the medal would be postponed until the February meeting.

3. The Secretary announced the publication of the Directory of Members of the Society in the *Journal of the Optical Society* for July 1931, noting that reprints were available for members who had need of them.

4. Transfers from Associate to Regular Membership. The name of each member elected during the year, and those previously elected and recommended for transfer, with recommendations from the Committee on Transfer were taken up in order, and the following members were transferred to Regular Membership:

JAMES BARNES (894 R)
HENRY A. BARTON (899 R)
HARRY CLIFFORD BATES (868 R)
HAROLD F. BENNETT (829 R)
H. J. C. IRETON (875 R)
HARVEY B. LEMON (872 R)
AARON LEVIN (866 R)
HERMAN E. SEEMANN (778 R)
SHIRLEIGH SILVERMAN (879 R)
ALFRED M. TAYLOR (877 R)
DAYTON ULREY (867 R)
JAY W. WOODROW (870 R)
REYNOLD K. YOUNG (876 R)

(*Signed*) L. B. TUCKERMAN, *Secretary*

SIXTEENTH ANNUAL MEETING

PROGRAM OF SESSIONS FOR CONTRIBUTED PAPERS

(TITLES AND ABSTRACTS OF PAPERS)

The abstracts were preprinted in the program subject to correction by the authors. Corrections that have been communicated to the secretary have been made in the abstracts reprinted below.

Thursday, October 22

9:15 A.M.

CONTRIBUTED PAPERS ON PHOTOMETRY AND COLORIMETRY

W. E. Forsythe and M. A. Easley — **Lamp Development Laboratory, General Electric Company**

A METHOD OF MEASURING THE MAXIMUM INTENSITY OF LIGHT OF THE PHOTOFLASH LAMP OR OTHER SOURCE OF SHORT DURATION

The photoflash lamp radiates about 50,000 lumen seconds in about .06 of a second. The maximum of this light intensity as measured by a photographic method has been found to vary from 3 to 5 million lumens. A method has been developed for measuring this maximum intensity by charging a condenser to the maximum voltage across a resistance carrying the current from a photoelectric tube which is exposed to the radiation from this flash lamp. There is an electric valve in the condenser circuit so that after the condenser has once reached the maximum charge it can not lose this charge. The current from the photoelectric tube that is exposed to the light from this lamp will vary with the variation of the intensity of the light. The fall of potential across the resistance carrying this current will also vary in this same manner. Thus the charge on the condenser which is due to the voltage drop across the resistance will be proportional to the light intensity of the lamp providing the time constants of the circuits are kept at the proper magnitude. The charge on this condenser, which gives us a meas-

ure of the light intensity of the lamp, is measured by the use of a very sensitive ballistic galvanometer. This photoelectric tube-resistance-condenser combination is calibrated by exposing the photoelectric tube to the light from incandescent lamps of known intensity. The relation between the intensity of the light falling upon the photoelectric tube and the resulting charge on the condenser was tested and found to be linear over the range that it was used, both for the momentary exposure such as that due to the photoflash lamp and for exposures to incandescent lamps of longer time.

Characteristics of photoflash lamps.

Total light output in lumen seconds	Maximum light output in lumens	Starting time lag in seconds	Time in seconds from start to maximum of flash	Duration of flash in seconds
45,200	3.2×10^6	.021	.014	.058

The present paper will appear in full in Review of Scientific Instruments.

F. Henning — **Physikalisch-technische Reichsanstalt**
H. T. Wensel — **National Bureau of Standards**

THE FREEZING POINT OF IRIDIUM

A value of 2726° K for the freezing point of iridium has been obtained which is accurate to 3° C. This result justifies the effort put forth only because from it data may be obtained which are greatly needed in connection with physical standards in other fields than pyrometry. Two instances from the field of optics will be briefly discussed.

A physical black body at the iridium point (accurately reproducible) has been maintained by immersing a hollow inclosure of fused thorium oxide in a bath of the freezing metal. It is planned to determine the voltage and current at which a number of gas-filled electric lamps will match the color of this black body. These lamps may then be relied upon as standards of color temperature in the neighborhood of 2725° K to the limit within which it is possible to match the color of two light sources at this color temperature.

The real purpose, however, for which the work was undertaken, was to obtain a group of candle-power standards at the color temperature of the iridium point, as described in the following abstract.

Bibliography:

"The Waidner-Burgess Standard of Light," Wensel, Roeser, Barbrow & Caldwell. B. S. Jour. Res. 6, p. 1103, 1931.

The present paper will appear in full in Bureau of Standards Journal of Research.

F. R. Caldwell, Wm. F. Roeser and L. E. Barbrow — **National Bureau of Standards**

PHOTOMETRIC STANDARDS BASED ON A BLACK BODY AT THE FREEZING POINT OF IRIDIUM

At present the various national laboratories agree fairly well on the unit of luminous intensity as maintained by carbon lamps. The agreement, however, is not at all good on the unit as represented by tungsten lamps which have been "stepped-up" from these carbon standards.

A group of six specially designed tungsten gas-filled lamps have been compared photometrically with a black body immersed in freezing iridium. The temperature of the black body has been determined as 2726° K. From this temperature and previously determined brightness and temperature of a black body immersed in freezing platinum it is possible to calculate the

brightness of the iridium light source. The candle-power assigned to this group of 6 lamps, on the basis of the calculated brightness and Gibson & Tyndalls visibility data, is correct within 1%. The data involved are summarized in the table below. The value 1200 candles per square cm was obtained on the basis of the value assigned to this group of lamps, by comparison with the Bureau's working tungsten standards.

		Brightness candles per cm²	
Fixed point	Temperature	Calculated	Observed
platinum	2046½	—	58.84
iridium	2726½	1224∓10	1244

While a difference of 3° C at the iridium point corresponds to a difference of 1% in brightness, the error in the *calculated* ratio of brightness for total light is considerably less than this, being no larger than that of the *experimentally* determined ratio of brightness for the red light used in the pyrometric measurements, which is certainly not as large as 1%.

Bibliography:

"The Freezing Point of Platinum," Roeser, Caldwell and Wensel, B. S. Jour. Res. 6, p. 1119, 1931.

The present paper will appear in full in B. S. Journal of Research.

A. H. Taylor — **Lighting Research Laboratory, General Electric Company**

THE MEASUREMENT OF REFLECTION-FACTORS IN THE ULTRAVIOLET

Previous investigators have measured the reflection-factors of various materials in the ultraviolet by a number of methods. Such measurements are not extremely difficult if only specular reflection-factors are to be measured, but if diffuse reflection-factors are required the measurements become much more difficult. Apparently none of the previous investigators have used an "absolute" method in measuring diffuse reflection-factors, i.e., one which does not require a standard surface.

The author has previously described* an absolute reflectometer for measuring the diffuse reflection-factors of plane surfaces for light. A new instrument based on the same principles has recently been designed and built for the measurement of diffuse spectral reflection-factors in the ultraviolet. The results given by this reflectometer are practically independent of the diffusion characteristics of the surface being tested. The essential parts of the apparatus consist of a 4-inch hollow sphere coated with magnesium oxide, a Hilger quartz spectograph to which has been attached a photo-electric cell in place of the photographic plate, a Mazda Sunlight lamp (Type S-1) in a quartz bulb and three quartz lenses. The light from the arc may be focused upon the test surface placed over an opening in one side of the sphere, at a point screened from the spot observed by the spectrograph, or upon the sphere wall at a point unscreened from the spot observed. The current from a quartz sodium photoelectric cell, produced by monochromatic radiation, is amplified by a direct current amplifier.

A method involving less apparatus has been devised by means of which the reflected radiation is weighted approximately in proportion to its effectiveness in producing erythema (reddening of the skin). While its results are less accurate than those obtained with the above apparatus, it is very useful in testing reflectors for use with artificial sunlight equipment.

Bibliography:

* Bureau of Standards Scientific Papers, No. 405; Trans. I. E. S., 15, Dec. 30, 1920, 811.

The present paper will appear in full in Review of Scientific Instruments.

F. M. E. Holmes and Brian O'Brien **Institute of Optics, Univ. of Rochester**

TRANSMISSION OF LIGHT BY FOG AND HAZE

The transmission of a horizontal light path 1.3 km long has been determined under various atmospheric conditions thruout the visible spectrum. Light from an incandescent lamp, collimated by a telescope mirror, is projected to a glass triple mirror 0.65 km distant, and returned adjacent to but not coinciding with the outgoing beam. A comparison beam is provided by two reflecting prisms with a stop between, and the two beams are received by an objective prism spectrograph. The comparison beam is adjusted to intensity match with the beam from the distant mirror by a variable sector disc rotated at a speed such that photographic reciprocity and intermittency defects compensate.[1]

Reference wave lengths are obtained by an absorption cell of didymium nitrate solution placed between the light source and the collimating mirror. The two adjacent spectra of nearly equal density are compared with a densitometer. On apparently clear nights the scattering is approximately proportional to $1/\lambda^4$, but is greater than that computed from the Rayleigh formula for the equivalent air path. For a fog of quite uniform droplets averaging 50 microns diameter, and having an optical density of 1.20 per kilometer, the variation in transmission with wave length was only that computed from the Rayleigh formula for the air in the path, the scattering due to the fog being nonselective, although 80 times that due to the air present. Under certain conditions in a clearing fog, and also in faint haze, Rayleigh scattering has been observed four or more times that due to air. The light path thus far used is too short to permit accurate study of very light haze, but within the accuracy of measurement it appears possible to represent the scattering by a term proportional to $1/\lambda^4$ plus a nonselective term.

Bibliography:

[1] O'Brien, Phys. Rev. 37, p. 471, (1931).

Brian O'Brien **Institute of Optics, University of Rochester**

REFLECTION FROM FINELY CRUSHED SEMITRANSPARENT MATERIAL

An optical glass with a pronounced absorption band in the blue (B. & L. Kalichrome) was crushed and sized into groups of particles whose effective diameters ranged by steps of $\sqrt{2}$ per group from 8 to 720 microns, and the diffuse reflecting power of the loosely packed powder measured with a spectrophotometer thruout the visible spectrum. Using extinction coefficients determined for the glass before crushing the variation of reflection factor with size of particle was found to be closely represented by the expression given by Stokes[1] for reflection from semitransparent plates, providing the effective diameter of the particles multiplied by a constant factor was substituted for the thickness of plates. This factor was independent of the size of particle but varied with particle shape, being greater for the elongated fragments crushed by impact than for more rounded forms produced by attrition, although both types showed characteristic conchoidal fracture. The factor increased slightly with increase in absorbed moisture, apparently due to effect on packing of the grains. When the product of effective diameter and extinction coefficient was kept constant the reflection factor was found constant within the accuracy of measurement, providing the shape of the particles was independent of size.

Bibliography:

[1] Stokes, Proc. Roy. Soc. 11, p. 545, (1862).

Deane B. Judd **National Bureau of Standards**

CHROMATICITY SENSIBILITY TO TEMPERATURE CHANGE AS A FUNCTION OF COLOR TEMPERATURE

Determinations at the same brightness by six normal observers have been made of the color-temperature difference corresponding to a chromatic difference just doubtfully percep-

tible over the range of 1,700 to 11,000° K. It has been found that this temperature difference corresponds closely to a constant difference in the spectral centroid of light (Priest's empirical relation).[1] This temperature difference is also closely proportional to the square of the color temperature (Davis' representation[2] of Priest's empirical relation). Furthermore this temperature difference corresponds with good approximation to a constant difference in the "red" trilinear coordinate (Judd's empirical relation).[3] These experimental results have therefore approximately checked three empirical relations previously derived from less complete data. Priest's spectral-centroid relation and Davis' representation of it both agree so closely with the experimental data that the discrepancies are not known to be real, but Judd's empirical relation yields discrepancies about twice as large as the experimental uncertainty.

A combination of the known properties of tungsten filaments[4] with these experimental results has yielded a statement of them in other terms: If a tungsten filament lamp be operated from constant line voltage at color temperatures varying between 1,700 and 3,100° K acccording to the external resistance of the circuit, a given increment in external resistance causes for the normal observer a chromatic change of the same size regardless of the color temperature.

The verification of Priest's spectral-centroid law permits a previous tentative conclusion[5] to be affirmed; that is, a given color temperature difference between 1,700 and 3,100° K causes for the normal observer nearly the same size chromatic difference regardless of whether the radiating surfaces be viewed directly or through a blue filter not more highly selective than a "daylight filter" provided the decreased brightness due to the filter does not itself decrease the chromatic difference.

Bibliography:

[1] I. G. Priest, "The Colorimetry and Photometry of Daylight and Incandescent Illuminants by the Method of Rotatory Dispersion," J.O.S.A. & R.S.I., 7, 1190–1191; 1923.

[2] R. Davis, "A Correlated Color Temperature for Illuminants," B. S. Jour. Research, 7, 659–681; 1931.

[3] D. B. Judd, J.O.S.A. & R.S.I., 16, 115; 1928.

[4] W. E. Forsythe and A. G. Worthing, "The Properties of Tungsten and the Characteristics of Tungsten Lamps," Astrophys. J., 61, 146–185; 1925.

[5] R. Davis and K. S. Gibson, "Filters for the Reproduction of Sunlight and Daylight, and the Determination of Color Temperature," B. S. Misc. Pub. No. 114; 79; January, 1931.

Deane B. Judd **National Bureau of Standards**

A GENERAL FORMULA FOR THE COMPUTATION OF COLORIMETRIC PURITY

An important means of specifying colors is to give the relative proportions of three colored lights (called primaries) required to match the colored sample. This is the tristimulus specification. Another means of specifying colors is to refer each color to some portion of the spectrum and to state how much heterogeneous ("white" or "neutral") light of known chromaticity must be mixed with the spectrum light to match the colored sample. This is homo-heterogeneous analysis and its terms are dominant wave length, colorimetric purity, and brightness. In the measurement of color it is frequently expedient to transfer from the tristimulus specification to the homo-heterogeneous specification; such transfers are particularly useful in interpreting spectrophotometric data. Methods of effecting these transfers are known for particular primaries, for particular definitions of "purity," and for particular choice of heterogeneous stimulus.[1] The present formula implicitly includes the equations of transformation from one set of primaries to another; hence it applies to any set of primaries. It also refers to any choice of heterogeneous stimulus and to any of the definitions heretofore proposed for "purity." This

formula suggests short methods in some cases of transferring color specifications from tristimulus terms to the terms of homo-heterogeneous analysis; it also constitutes a unified system into which all previous methods may be fitted and reveals the arbitrary aspect of each of the particular formulas.

Certain of these particular formulas have been proposed to represent quantitatively the concept, "satufation." On this account the two indispensable concepts, "purity" and "saturation" have both become confused. The conditions which a number, s, deserving the name, "saturation," must fulfill are: (1) $s=0$ for any achromatic color, and (2) $s_1=s_2$ for two colors appearing to be equally saturated. No special case of the general formula satisfies both these conditions. However, the integral of the purity sensibility has been used by Jones and Lowry[2] as a numerical evaluation of saturation. This definition promises well and deserves experimental attention.

Bibliography:

[1] L. T. Troland, "Report of the O.S.A. Colorimetry Committee for 1920–21," J.O.S.A. & R.S.I., 6, 527–596; 1922.

I. G. Priest, "The Computation of Colorimetric Purity," J.O.S.A. & R.S.I., 9, 503–520; 1924.

D. B. Judd, "The Computation of Colorimetric Purity," J.O.S.A. & R.S.I., 13, 133–154; 1926.

[2] L. A. Jones and E. M. Lowry, "Retinal Sensibility to Saturation Differences," J.O.S.A. & R.S.I., 13, 25–34; 1926.

The present paper will appear in full in J.O.S.A.

Thursday, October 22

2:00 P.M.

CONTRIBUTED PAPERS ON OPTICAL INSTRUMENTS AND PHYSICAL AND CHEMICAL OPTICS

Armand de Gramont — **Institut d'Optique, Paris, France**

(*Presented by the Secretary*)

THE INFLUENCE OF SURFACE POLISH UPON THE LIGHT TRANSMITTED IN "TOTAL" REFLEXION

M. de Gramont again takes up the study of transmitted light in the case of "total" reflexion which he published in the Revue d'Optique in March 1931.

Referring to that article, the reader will find diagrams of the optical arrangements used and photographs which give an idea of the phenomenon studied.

In the present article M. de Gramont describes a portable apparatus which permits a rapid comparison of the polish of different surfaces.

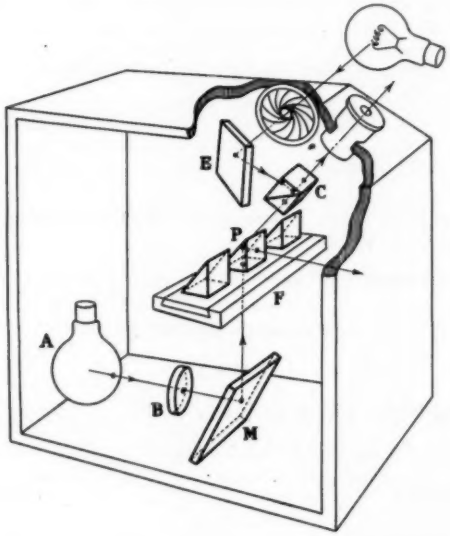
Inside of a blackened wood box is placed a lamp A, which is covered with opaque varnish except for a small area which limits a pencil of light from the source. The lens B converges the pencil of light, which, after reflection at the mirror M, forms an image of the source on the hypothenuse of the prism P. The transmitted light falls upon a Lummer cube C which is observed through a diaphragmed eyepiece.

The comparison light on the Lummer cube comes from the outside lamp D in front of a

ground glass set in the wooden box. An iris diaphragm permits varying the illumination of the diffusing screen E which is viewed through the cube.

The prisms to be compared are mounted on the slide F and can be rapidly interchanged. The opening of the iris diaphragm which can be graduated in terms of the intensity of illumination, gives a measure of the polish of the surface.

Measures were made on three prisms which, to the naked eye, showed hardly any difference in their surfaces. One had been freshly polished in the shop. On the other two the polishing operation had been purposely stopped at different stages before the polishing was complete. Under these conditions, measurements of the ratio of the brightness of the light transmitted in the direction observed, to the illumination of the hypothenuse of the prism gave the following:



	Ratio of brightness
(a) Surface with perfect polish	0.5×10^{-4}
(b) Surface with imperfect polish	1.7×10^{-4}
(c) Surface with mediocre polish	$15.\times10^{-4}$

For a surface simply fine ground ratios 100 times as large were observed.

The method is very simple, but has the disadvantage that the values obtained depend upon the condition of the surface at which the light enters, as well as upon the hypothenuse at which it is reflected. It does not, as does Urbanek's method, give a value depending only upon the condition of a definite point of a given surface.

The maximum brightness is found at a well defined angle of emergence. It is noteworthy that this angle remains practically constant (about 18° with the surface) for glasses of widely different indices of refraction (borosilicate $n=1.51$ and dense flint $n=1.62$)

It may be possible to explain this by the assumption of a transition layer, but the necessary hypotheses are still very uncertain.

Oran E. Miller **Kodak Research Laboratories**

WEDGE SPECTROGRAMS WITHOUT AN ABSORBING WEDGE

This paper describes a special type of the optical device consisting of a cylindrical condenser and a suitably graduated diaphragm employed to replace the black glass wedge of a wedge spectrograph. The advantages obtained are the elimination of spectral selectivity, easier and more accurate reproducibility, and the freedom to choose a scale of intensity which varies in any desired manner by properly shaping the diaphragm. While the instrument described has glass lenses and its usefulness is limited largely to work in the visible spectrum, the system should be very easily applicable to a spectrograph having quartz fluorite lenses throughout for work in the ultraviolet region. This instrument has been found quite useful in the measurement of the spectral sensitivity of photographic materials and in a number of other problems. Its use as a photographic spectrophotometer is suggested.

The present paper will appear in full in Review of Scientific Instruments.

Gustave Fassin **Bausch & Lomb Optical Company**

MEASURING MICROSCOPE AND DENSITOMETER FOR SPECTROGRAMS

A new screwless measuring microscope comprises a base on which is mounted a slide carriage which can be moved by means of a steel band. Fixed to the carriage and movable therewith is a glass plate on which a scale is engraved. An image of the scale is projected through a microscope onto a ground glass screen which is secured to the base of the instrument in front of the measuring microscope. The image of a fixed vernier scale is also projected onto the screen thereby providing one-one hundredth of a millimeter by direct reading with 2-5-7.5 microns estimated.

A spectrum plate or other object is supported on the carriage and the projection lamp also serves to illuminate the spectrum plate. The measuring microscope can be removed and replaced by a slit projector so that with a photoelectric cell, in the base of the instrument, and suitable amplifying means a densitometer is provided.

K. Hickman and C. R. Sanford **Eastman Kodak Company**

A BOLOMETER FOR AUTOMATIC OPTICAL CONTROL

The relative merits of thermopiles and bolometers for the absolute measurement of radiation are well known. When, however, a robust indication is required for industrial purposes the bolometer has the advantage that the current available can be independent of the sensitivity, whereas the current from a thermopile diminishes with increase of sensitivity. The present bolometer has been constructed from cones of nickel wire sealed in a bulb filled with hydrogen. The half period is less than 1 second and the available indication for the purpose in hand is from 100–1000 millivolts and 5–50 milliamperes. The bolometer has been used to inspect automatic chemical titration operations, in which it actuates relays and control valves, without the inclusion of amplifiers.

The present paper will appear in full in Review of Scientific Instruments.

R. Kingslake **Institute of Applied Optics, University of Rochester**

A NEW BENCH FOR TESTING PHOTOGRAPHIC LENSES

In planning the equipment for the recently established Institute of Applied Optics at the University of Rochester, it was decided to build a photographic-lens testing bench, which should be suitable both for instruction to students and for research work. A complete description of the construction, adjustment and use of the bench is given in the present paper.

In designing the bench, it was decided to use a distant point or other source of light, and to

mount the lens so that it can be rotated about a vertical axis through its second nodal point, and set at any desired obliquity up to 60°. The image formed by the lens is then examined with a microscope in the usual way. Following the suggestions in Mr. T. Smith's paper on the nodal-slide bench*, it was decided to incorporate an automatic mechanism to ensure that the focusing point of the microscope is always in the ideal flat field which the lens should have; and further, to provide such auxiliary motions as are necessary to test telephoto lenses.

Scales are provided for the direct measurement of astigmatism, curvature of field, distortion, and oblique color; and by suitable means it is also possible to determine the amount of spherical and chromatic aberration should this be required. The range of focal lengths is from 5 to 60 cms, with a provision for the direct measurement of the equivalent focal length and the back focus of the lens.

The bench contains within itself adequate means for making complete adjustments of all its parts, and for correctly setting the zeros of all scales.

Bibliography:

* T. Smith and J. S. Anderson—"A Criticism of the Nodal Slide"—Trans. Opt. Soc. 23 (1921–22) 188–196.

Harold F. Bennett **National Bureau of Standards**

DIFFERENCES IN PATH LENGTH THROUGH A LENS IN TERMS OF ITS RECIPROCAL SPHERICAL ABERRATION

The wave theory of light gives a greater insight into the details of optical imagery than does classical geometrical optics, although the latter is correct in its broad outlines. There is, however, a close relationship between the two, investigations by means of the wave theory being based upon differences in path lengths between object and image points, and equations for this being in turn derivable from those of geometrical optics.

L. C. Martin[1] has carried out the integration for the intensity at points near an axial focus in a symmetrical optical system, using as a variable of integration the height at which a ray intersects the wave front passing through a fixed axial point and assuming the spherical aberration to be expressed in terms of the same variable. It is evident that this is not a convenient variable in which to express spherical aberration, since the shape of the wave front is not generally known.

In the present paper the constants of the equation for difference in path length, expressed in a form suitable for use with Martin's method of integration, are derived from the equations for reciprocal spherical aberration which appear in a paper presented to this society last year.[2] It is found that the reciprocal spherical aberration of the order which varies as the square of the aperture corresponds to a path length difference which varies as the fourth power. Formulas have been derived for orders up to that in which the spherical aberration varies as the tenth power of the aperture. Incidentally, an equation expressing the form of the wave front is derived, and finally some consideration is given to the question of locating the particular wave front which passes through the boundaries of the exit pupil.

Bibliography:

[1] Trans. Opt. Soc. London; 23, 63–92. 1921–22.

[2] Not yet printed. See abstract, J.O.S.A.; 21, 142, March, 1931.

Reinhard A. Wetzel **University of Jena and the College of the City of New York**

PHOTOGRAPHS OF THE LUMMER "DOUBLING" OF INTERFERENCE FRINGES OF EQUAL SLOPE IN POLARIZED LIGHT

When monochromatic light falls on a plane parallel plate the reflected and transmitted interference fringes due to repeated reflections have peculiar characteristics. Lummer called

them "Equal Slope Fringes" to distinguish them from "Interference Fringes of Equal Thickness" obtained with thin wedges. Lummer (1907) was first to study equal slope fringes in polarized light and found a peculiar doubling of the fringes at certain azimuths of the analyzing nicol.

With the equipment at his disposal at Jena the writer was unable to reproduce some of the phenomena Lummer saw and Prof. Jentzsch suggested a reinvestigation substituting camera for eye. As the amount of light available for photography was limited the "Leica" camera with which the pictures were obtained proved a real time saver.

Since the fringes which arise at the cemented surfaces of nicols at times superimposed themselves on the phenomena under study California tourmaline was used for polarizer and analyzer.

Bibliography:

Lummer, Ann. d. Physik 22: 63, 1907.

W. W. Sleator **University of Michigan**

THE ELLIPTIC POLARIZATION OF LIGHT BY TOTAL INTERNAL REFLECTION

If plane polarized light is totally reflected within glass, so that the plane of polarization is inclined to the plane of incidence, the totally reflected light is elliptically polarized. The parallel and perpendicular components of the light vector experience each a change of phase at reflection which is different for the two. Apparently every writer since Fresnel's time has followed him in calculating the amounts of these changes by the use of imaginaries, and one may study any of these accounts without finding out why the changes occur. In this paper the physical reason for the changes is presented and the amounts are calculated without the use of imaginary quantities. A vector treatment enables the reader to follow the whole process from the physical point of view.

The essential idea is that if at the boundary of the medium there are three differently directed values of the light vector, as there are in ordinary reflection with refraction, then the three make a closed triangle and no phase change at reflection can possibly occur. But if there are four differently directed vectors, then one of them may become zero while the others, which are not zero, still make up a closed figure while preserving their original directions. In this case there may be a phase difference at the surface. To show that four such differently directed vectors occur in total internal reflection, though there are only two beams of light, and to evaluate them, is to explain and account for the elliptic polarization.

Bibliography:

Wood., Physical Optics, Pages 330 and 371. Müller-Pouillets, Lehrbuch der Physik, II, 2, 1, p. 1582.

E. L. Nichols **Cornell University**
Frances G. Wick **Vassar College**

THE RELATION BETWEEN CERTAIN TYPES OF LUMINESCENCE

Rare earths in solid solution were excited by cathode rays, ultraviolet radiation (iron spark with screen), and exposure to the hydrogen flame respectively, with the following results:

(*a*) The luminescence spectra in all cases contain narrow bands characteristic of the activator, irrespective of the mode of excitation.

(*b*) The bands are best observed in the spectrum of cathodo-luminescence, only the stronger ones appearing under flame or u.v. excitation.

(*c*) No bands not found in the cathodo spectrum appeared when the other modes of excitation were used.

(*d*) Previous exposure to one mode of excitation, e.g., the hydrogen flame, frequently enhanced the luminescence due to another mode, seemingly by starting or facilitating the reversible reduction-oxidation process.

Bibliography:

Nichols & Howes: J.O.S.A. 13, p. 573 ff.

Wick: Phys. Rev. (2) 24, p. 272 ff.

The present paper will appear in full in J.O.S.A.

David I. Macht — **Pharmacological Research Laboratory Hynson, Westcott and Dunning, Inc.**

INFLUENCE OF ULTRAVIOLET RAYS ON PHARMACOLOGICAL POTENCY OF DIGITALIS

Digitalis, the most important heart drug at the disposal of the physician, varies markedly in its pharmacological activity, even the alcoholic extracts deteriorating often within a comparatively short time. In the present investigation, pharmacological activity of the tincture of digitalis was studied after its exposure to various ultraviolet rays. A standard tincture was kept in the ice-box. Samples of this tincture were irradiated with a Kromayer lamp with and without filters, and the biological activity was ascertained. The assay was made by three different methods: (1) the official one-hour frog method, (2) the cat method of Hatcher and Brody, and (3) the phytopharmacological method of Macht and Krantz.

It was found that irradiation with ultraviolet rays produces deterioration of the tincture within ten minutes. Prolonged irradiation produces greater deterioration up to a certain point, namely, one and a half hours of exposure. Further irradiation after that period produces photochemical changes resulting in a greater toxicity or potency of the drug. Still further irradiation, however, as for a period longer than two and a half hours produces a second and more marked deterioration than that effected by short exposures. The longer ultraviolet rays produce little change in digitalis; the shorter rays produce the above sequence of events more rapidly. Exposure of tincture of digitalis to x-rays, radium and radium emanations induces changes which render the drug much less toxic for animals but more toxic for living plants.

Bibliography:

[1] United States Pharmacopoeia. Tenth Revision. (Tincture Digitalis, Assay).

[2] Hatcher and Brody: American Journal of Pharmacy, 1910, 82, 360.

[3] Macht and Krantz: Jour. Pharmacol. and Exper. Therap., 1927, 31, 11.

The present paper will appear in full in J.O.S.A.

Friday, October 23

3:00 P.M.

CONTRIBUTED PAPERS ON PHOTOGRAPHY

Committee on Photographic Standard of Intensity

K. S. Gibson (Chairman); B. H. Carroll, E. C. Crittenden, R. Davis, A. C. Hardy, H. E. Ives, L. A. Jones, C. E. K. Mees, A. G. Worthing.

REPORT OF THE COMMITTEE AND ACTION TAKEN AT THE EIGHTH INTERNATIONAL CONGRESS OF PHOTOGRAPHY

Copies of the report of the American (O.S.A.) standardization committee, appearing in J.O.S.A. for October, 1931, were transmitted to the secretaries of the British, French, and German standardization committees the latter part of April, 1931. This report urged the accep-

tance of the recommendation of the Seventh International Congress (London, 1928) with respect to the adoption of the artificial sunlight (source-filter combination) proposed in 1928 by the previous American committee for use in photographic sensitometry. Objection to the proposed filter had been raised by various members of the other national standardization committees, and the larger part of the American report was devoted to meeting these objections.

Official word has not yet been received (at the time of writing this abstract) regarding action taken by the Eighth Congress (Dresden, Aug., 1931); but according to reports appearing in European journals[1] the various objections to the recommended filter were withdrawn, and the recommendation of the previous Congress (reworded) relating to the source of light was officially accepted.

Certain proposals regarding sensitometric procedure were made by the German committee and the several national standardization committees have been requested to study these proposals and report their conclusions before February 15, 1932.

Bibliography:

[1] Photographische Industrie, Aug. 19, 1931. Science et Industries Photographiques, p. 351, Sept., 1931.

C. E. K. Mees — **Research Laboratories Eastman Kodak Company**

PHOTOGRAPHIC PLATES FOR USE IN SPECTROSCOPY

Photographic plates can be of many kinds, and the choice of the correct plate for each purpose involves a knowledge of the plates available.

Specific information is given as to the characteristics of the plates supplied for scientific use by the Eastman Kodak Company.

Photographic materials differ in speed and contrast, in color and sensitivity, in resolving power and in graininess. The standards by which speed is measured are described and a suggestion is made as to the best method of defining speed for spectroscopic and astronomical work, following Theodore Dunham, Jr. Tables and figures show the graininess and resolving power of the materials as well as the variation of resolving power with the contrast of the object and the optical density of the image. The plates sensitive to various spectral regions are then discussed in detail, a description being given of a new method of sensitizing for the ultraviolet and an analysis of the spectral sensitivity of the plates available for the visible spectrum. The paper closes with a discussion of the materials available for the photography of the infrared.

H. E. Ives — **Bell Telephone Laboratories, Inc.**

PROJECTION IN RELIEF AND COLOR

Projection in both relief and color may be achieved by a combination of the Kodacolor process with the methods for relief projection previously described.[1] In order to obtain a photographic record suitable for relief projection, a concave mirror of four feet diameter, is used. The light from this is reflected downward by a half silvered mirror onto a transparent screen of dimensions 10 inches by 12 inches with 80 concave ridges which is placed at the focus of the concave mirror. The concave ridged screen forms a multitude of minute panoramic images of the object, located close to the plane of the screen. These images are then photographed onto Kodacolor film through a lens provided with the usual colored apertures; the apertures and the ridges on the film are turned so as to be at right-angles to the panoramic strip images, to avoid patterning. The resultant picture after development and reversal is projected through a Kodacolor projector, with its color filters horizontal, upon the rear of the convex rod screen previously described, giving a picture exhibiting color and relief. Both features are recorded by microscopic lines, the two sets of lines running at right-angles to each other. Convex ridges

serve to distribute the light in each case, the ridges on the film controlling the color distribution, the ridges on the projection screen controlling the distribution in direction on which relief depends.

Bibliography:
[1] Ives, J.O.S.A., July, 1931, p. 397.

H. F. Kurtz — **Scientific Bureau, Bausch & Lomb Optical Company**

A CAMERA AND STEREOSCOPE FOR ORTHOSTEREOSCOPIC PICTURES AT MAGNIFICATIONS FROM UNITY TO 24X

The conditions that must be met for orthostereoscopy are established by the following equations:

M_1 = photographic magnification.
M_2 = stereoscope magnification.
d = assumed nearest distance of comfortable vision
p = interpupillary distance

$$\frac{M_1}{M_2} = k$$

For the camera:

Lens separation	$= p/M_2$
Lens to object	$= d/M_2$
Lens to plate	$= kd$
Focal length lens	$= kd/(M_1+1)$
Plate center separation	$= kp/(1+1/M_1)$

For the stereoscope:

Magnification	$= 1/k$
Focal length lenses	$= kd/(1-k)$
Lens separation	$= p$
Lens to picture	$= kd$
Picture separation	$= p/(1-k)$

A brief discussion of these equations will be given.

A camera and stereoscope meeting the above conditions and characterized by extraordinary simplicity in manipulation will be described.

R. P. Loveland — **Research Laboratories, Eastman Kodak Company**

AN APPARATUS FOR MOTION PHOTOMICROGRAPHY WITH 35 MM FILM

It was necessary to set up apparatus to make motion photomicrographic scenes for production purposes at some distance from its permanent location. A description is given of the semi-portable apparatus that was developed together with a discussion of the requirements for the purpose. Each unit should be as much separated from physical contact with the rest of the system as possible. Since a horizontal stage is usually necessary for this work the light lock between the camera and microscope (or split prism observation eyepiece) should be vertical. Therefore it must be possible to raise and lower the camera vertically, or swing it aside when convenient, and yet support it with absolute stability, free from the influence of external vibrations. A comparatively economical driving unit is described that will allow a speed variation in intervals from twice normal cranking speed to that of one frame every four minutes with an interval factor of two.

AN INTERFEROMETER METHOD OF STUDYING THE VIBRATIONS OF AN OSCILLATING QUARTZ PLATE

By Harold Osterberg

[Department of Physics, University of Wisconsin, Madison, Wisconsin. Received September1 4, 1931]

ABSTRACT

An expression involving the fringe brightness as a function of the amplitude of vibration is obtained for the case of a Michelson or a similar interferometer in which one of the returning mirrors executes S.H.M. in a direction perpendicular to its plane. A detailed discussion of the application of this expression to the measurement of the amplitude of vibration of a quartz plate is given, together with the observations upon four such plates. The superposition of either the first or second overtone upon the fundamental is also considered.

The observed vibrations are predominantly flexural. The experimental results of Doerffler relating to the frequency dependence of the velocity of flexural waves are confirmed and found to apply to X-waves in a Y-cut. There is evidence of low frequency flexural waves propagated diagonally across a quartz plate.

An interferometer method is suggested for distinguishing between flexural and longitudinal vibrations.

Recent years have witnessed a growing interest in the study of small vibrations, particularly in the case of quartz rods and plates. Since 1927 publications relating to interferometer methods of determining the amplitudes and patterns of small mechanical vibrations have been made by Thomas and Warren,[1] P. Paasche,[2] and the author.[3] The amplitude of vibration of a quartz rod has been measured by T. Fujimoto[4] and used to check the theory of longitudinal vibrations in quartz rods by W. G. Cady.[5] An unpublished measurement of the amplitude of oscillation of such rods has also been made by W. G. Cady and his students. A brief description of patterns viewed stroboscopically in conjunction with a Michelson interferometer by D. W. Dye has been given by A. B. Wood.[6]

Where the stroboscope has been unavailable, or its use unsuccessful, the amplitude of oscillation, as judged from the appearance of the disturbed fringe system, has been in considerable error due to the failure to take properly into account the distribution of light in the oscillating fringe system. This article presents a mathematical theory of the measurement of small amplitudes of vibration by an interferometer method and the observations made upon four quartz plates.

[1] Thomas and Warren, Philosophical Magazine *5*, 1125; 1928.
[2] P. Paasche, ZS. für Technische Physik *9*, 411; 1928.
[3] H. Osterberg, Proceedings of the National Academy of Science *15*, 892; 1929.
[4] T. Fujimoto, Thesis, Ohio State University (1927).
[5] W. G. Cady, Physical Review *19*, 1; 1922.
[6] A. B. Wood, *A Textbook of Sound*, p. 165.

MATHEMATICAL THEORY

A lateral shift of the straight line fringes produced in the usual way in the case of the Michelson or a similar interferometer is observed when one of the reflecting mirrors is moved in a direction perpendicular to its plane. Simple harmonic motion of the surface, and consequently of the fringe system, may be produced as in quartz by the converse piezoelectric effect or by attaching the reflecting interferometer mirror to a vibrating mechanical system such as reed or membrane. The resultant brightness at any point in the oscillating fringe system is, in general, a function of both the time and the amplitude of oscillation. In the following treatment it is assumed that the frequency of oscillation is twenty-five per second or more so that the visual brightness at any point may be found by securing at that point the time average of the instantaneous brightness.

Let the brightness of the fringes produced by the surface at rest for the case of uniform illumination over the mirrors and equal intensity of the two interfering beams be denoted by I_0. It can be shown that

$$I_0 = K\left[1 + \cos\frac{2\pi x}{h}\right], \tag{1}$$

where K is a constant, h is the fringe width, and x is the distance measured perpendicularly across the fringes.

The motion of a reflecting mirror is assumed to impart to the fringes a simple harmonic motion of amplitude R and frequency $1/T$. At any point the instantaneous brightness, I_i, is therefore given by

$$I_i = K\left[1 + \cos\frac{2\pi}{h}\left(x - R\cos\frac{2\pi t}{T}\right)\right]. \tag{2}$$

Denote the resultant brightness by I. It is the time average of I_i.

$$I = \frac{2K}{T}\int_0^{T/2}\left[1 + \cos\frac{2\pi}{h}\left(x - R\cos\frac{2\pi t}{T}\right)\right]dt, \tag{3}$$

or

$$I = K\left[1 + \frac{1}{\pi}\cos\frac{2\pi x}{h}\int_0^{\pi}\cos(z\cos\phi)d\phi + \frac{1}{\pi}\sin\frac{2\pi x}{h}\int_0^{\pi}\sin(z\cos\phi)d\phi\right], \tag{4}$$

where

$$\frac{2\pi R}{h} \equiv z \quad \text{and} \quad \frac{2\pi t}{T} \equiv \phi. \tag{5}$$

Now

$$\int_0^\pi \text{sine } (z \cos \phi) d\phi = 0^{7} \tag{6}$$

and

$$\frac{1}{\pi} \int_0^\pi \cos (z \cos \phi) d\phi = J_0(z),^{8} \tag{7}$$

where $J_0(z)$ is a Bessel function of order zero.

Let λ denote the wave length of light employed and r the amplitude of oscillation of the mirror surface. Then

$$\frac{R}{h} = \frac{2r}{\lambda}. \tag{8}$$

When (5), (6), (7), and (8) are substituted into (4),

$$I = K\left[1 + J_0\left(\frac{4\pi r}{\lambda}\right) \cos \frac{2\pi x}{h}\right]. \tag{9}$$

APPLICATION OF THE THEORY

For the discussion of the application of (9) to the measurement of r, let the fringes given by (1) be denoted as the I_0 fringes and those given by (9) as the I fringes. A comparison of (9) and (1) shows that either the maxima of I and I_0 occur for the same value of x or are one-half fringe width out of step according as $J_0(4\pi r/\lambda)$ is positive or negative. When $J_0(4\pi r/\lambda) = 0$, $I = K$, and no fringes are visible. Maximum contrast of the I fringes occurs when the absolute value of $J_0(4\pi r/\lambda)$ is a maximum. Since the maximum value of $J_0(4\pi r/\lambda) = J_0(0) = 1$, the fringes display the greatest contrast only when the interferometer mirror is stationary. For this case (1) and (9) become identical.

In Table 1 are assembled those values and characteristics[9] of $J_0(4\pi r/\lambda)$ which are of most use in the measurement of r. In the interval $0 < r/\lambda < 0.191$, $J_0(4\pi r/\lambda) > 0$. Consequently, the I fringes for these amplitudes are in line with the I_0 fringes. The effect of these small amplitudes is to partially blur the I_0 fringes as illustrated by spot a of photograph $I(4)$. When $r/\lambda = 0.191$, $J_0(4\pi r/\lambda) = 0$. Hence, no fringes are visible.

[7] Gray, Matthews, and Macroberts, *Bessel Functions*, 1922, p. 46.
[8] Byerly, *Fourier Series and Spherical Harmonics*, 1893, p. 222.
[9] Gray, Matthews, and Macroberts, *Bessel Functions*, 1922, pp. 267–287.

In the interval $0.191 < r/\lambda < 0.438$, $J_0(4\pi r/\lambda) < 0$. Here the I fringes are shifted by one-half fringe width with respect to the I_0 fringes and the greatest contrast is reached at the point $r/\lambda = 0.304$ since at this point $J_0(4\pi r/\lambda)$ is a minimum. At $r/\lambda = 0.438$ no I fringes are again visible. In the interval $0.438 < r/\lambda < 0.688$, $J_0(4\pi r/\lambda) > 0$. The maxima of I and I_0 coincide. Greatest contrast occurs at the point $r/\lambda = 0.558$. These characteristics of the I fringes are repeated in the succeeding intervals in r/λ. Successive intervals are found, however, to display poorer fringe contrast because as r/λ increases the peak values of $J_0(4\pi r/\lambda)$ decrease (see Table 1).

TABLE 1.

Values of $J_0(4\pi r/\lambda)$		r/λ	R/h	Eighths	Interval in r/λ	Sign of $J_0(4\pi r/\lambda)$
First max. =	1.000	0.000	0.000	0/8=0.000	0.000–0.191	+
	0.000	0.191	0.382	1/8=0.125		
First min. =	−0.403	0.304	0.608	2/8=0.250	0.191–0.438	−
	0.000	0.438	0.876	3/8=0.375		
Second max. =	0.3001	0.558	1.116	4/8=0.500	0.438–0.688	+
	0.000	0.688	1.376	5/8=0.625		
Second min. =	−0.2497	0.808	1.616	6/8=0.750	0.688–0.938	−
	0.000	0.938	1.876	7/8=0.875		
Third max. =	0.218	1.049	2.098	8/8=1.000	0.938–1.189	+
	0.000	1.189	2.378	9/8=1.125		
Third min. =	—	—	—		1.189–1.44	−
	0.000	1.440	2.880	11/8=1.375		

It is of great convenience that the straight line Michelson interferometer fringes are localized in the mirror surface, so that when a piezoelectrically driven quartz surface is substituted for one of the interferometer mirrors, its surface condition is shown by the fringes. On account of the property of the quartz surface to oscillate in parts, I and I_0 fringes are seen simultaneously, the I fringes appearing on those parts of the surface which are in motion. $I(4)$ and $I(6)$ have been photographed from such a surface, $I(6)$ being the same pattern as $I(4)$ but with the applied voltage tuned more sharply to the crystal frequency. The application of Table 1 to these photographs will be discussed in the following paragraphs.

In Fig. 1 AB represents the equilibrium position of the crystal surface. 1-2-3, 4-5-6, 7-8-9, etc., represent in the order of increasing amplitude the upper extreme positions of the surface when attention is confined to a single vibrating surface portion. The amplitude scale is given at the left in terms of r/λ.

When the extreme position is A-1-2-3-B, I_0 fringes appear on the portions A-1 and 3-B; I fringes, with maxima in line with those of I_0, on 1-2-3. This is the situation in spot a of $I(4)$. The next stage of development is A-4-5-6-B. At 5 $r/\lambda = 0.191$. Hence in the vicinity of 5 the fringes are completely blurred. In spot b the amplitude at 5 is almost reached.

The fringe appearance is more complicated for the position A-7-8-9-B. The fringes on the portions 7-a and b-9 are in line with the I_0 fringes on the portions A-7 and 9-B. At a and b, $J_0(4\pi r/\lambda) = 0$. In their vicinity the

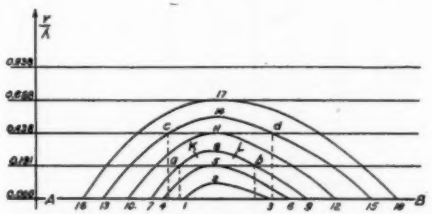


FIG. 1

fringes are obliterated. The fringes on a-8-b are out of step with the surrounding fringes since $J_0(4\pi r/\lambda) < 0$. All points such as a and b, in the vicinity of which the fringes are destroyed, therefore separate portions on which the fringes are out of step. This completely blurred area of demarcation is very narrow when the slope of the surface at a or b is but little different from zero and marks sharply those amplitudes for which $J_0(4\pi r/\lambda) = 0$. Spots c, d, e and f of $I(4)$ are examples of this condition. The narrow area of demarcation bounding the staggered I fringes is clearly visible. In the interval $0.191 < r/\lambda < 0.438$ there is one position of 8 such that along K-8-L, $J_0(4\pi r/\lambda)$ is a minimum. The fringe contrast on K-8-L is greatest at this amplitude. It may be remarked that K-8-L is not flat topped. Fig. 1, however, cannot be drawn to the proportions of a characteristic spot. Thus, for example, the length of g in $I(6)$ is 10^4 as great as its maximum height. A section similar to K-8-L is therefore extremely flat topped. The necessary requirement on the area of the flat top whose amplitude of vibration is to be measured is that it be possible to produce two or more fringes upon it. From the appearance

of d and c in $I(4)$, it can be seen that d oscillates with greater amplitude than c since in d the amplitude producing greatest contrast is almost reached. The amplitude in c has not passed this value because in this event a blur would have been visible upon the central part of c. The conclusion that d oscillates more vigorously than c is readily seen by a direct comparison of c and d in both $I(4)$ and $I(6)$.

g and h of $I(6)$ are examples of the case A-13-14-15-B. The fringes on c-d are out of step with those on 13-c and d-15. The fringes on 13-c and d-15 are, in turn, one-half fringe width out of step with the surrounding

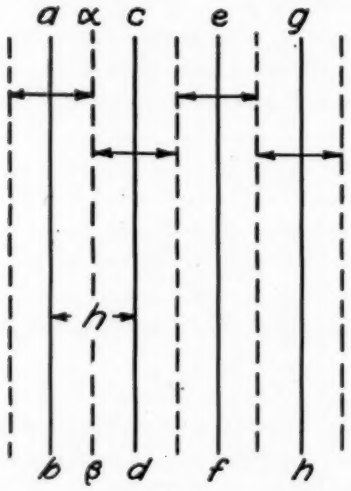


FIG. 2

I_0 fringes. The narrow area of demarcation corresponding to that in the vicinity of points c and d of Fig. 1 is indicated by *2* in $I(6)$.

When the crystal is made to oscillate more vigorously than in $I(6)$, a further number of blurs appear in succession upon the central portions of d, e, and f and consequently build up a series of regions in which the fringes are one-half fringe width out of step. With the aid of Table 1 and some interpolation of the state of contrast attained, it is not difficult to estimate the amplitude of oscillation to one-tenth of the wave length of light employed.

It is instructive to consider the formation of the I fringes from a graphical point of view. In Fig. 2, ab, cd, ef, and gh represent the locations of maximum brightness in a set of stationary fringes. These maxima oscillate between the extremes indicated by the arrows or with an ampli-

tude of S.H.M. equal to $h/2$ for the special case in which the amplitude of surface vibration is $\lambda/4$. The maxima of brightness in this oscillatory fringe group are located along the broken lines since the fringe velocities are smallest at the extremes of the path and since the oscillating maxima are superposed at the path extremes. Similarly, the maxima of the I fringes are located along the broken or full lines according as $n\lambda/4$ is an odd or even number of fourths. It is not to be concluded that these amplitudes of oscillation produce the best fringe contrast. Referring to Fig. 3 in which the full curve represents the graph of I_0 as a function of x, it is seen that the brightness at the point $h/2$ is increased when the maximum a oscillates with an amplitude aa' greater than ad. There is then an advantageous overlapping of the brightnesses in the peaks b' and a' at $h/2$. The optimum of overlapping may be secured from Table 1. There is an optimum amount of such overlapping for all amplitudes $n\lambda/4$, at which the I fringes are reconstructed.

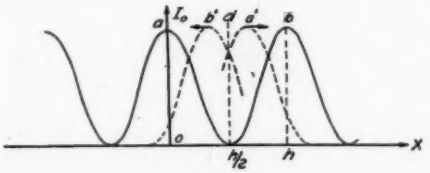


FIG. 3

The error made by those investigators who have concluded that greatest fringe contrast occurs for amplitudes of oscillation equal to $n\lambda/4$ is evident from Table 1. Thus the first minimum of $J_0(4\pi r/\lambda)$ occurs for $r/\lambda = 0.304$ instead of $1/4$. The error is 17%.

Since the use of the interferometer method may be extended to the study of larger vibrations, such as those of a membrane, in which the presence of overtones is to be expected, it has been of interest to investigate the effect of the presence of the harmonics of the vibrating surface upon the fringe disturbance. This effect can be found to any desired degree of approximation. A summary is here given of the results obtained for two important cases: the presence of the fundamental with (*a*) its first harmonic and (*b*) its second harmonic.

Let the fundamental, the first overtone, and the second overtone vibrate with the amplitudes r, α, and β respectively and let the corresponding amplitudes of the fringe motion be R, A, and B. Let λ, h, x, z, and ϕ be defined as before. Let also

$$M \equiv \frac{4\pi A}{h}; \qquad N \equiv \frac{8\pi B}{h}. \tag{10}$$

I_1 and I_2, the resultant fringe brightness for case (a) and (b) respectively, are now secured in essentially the same manner as I in (9). In evaluating the complicated integrals for I_1 and I_2 it is convenient to resort to expansions of the integrands into trigonometric series and to refer to exercises (2) and (3) of Byerly.[8] The details of this calculation can be found in the thesis filed at the University of Wisconsin Library.

$$I_1 = K\left[1 + \sqrt{\rho_1^2 + \rho_2^2}\cos\left(\frac{2\pi x}{h} + \gamma\right)\right]. \tag{11}$$

$$I_2 = K\left[1 + \rho_3 \cos\frac{2\pi x}{h}\right]. \tag{12}$$

Where

$$\rho_1 = J_0(z)\left(1 - \frac{M^2}{2}\right) + \frac{M^2}{z}J_1(z) - \frac{3M^2}{2z^2}J_2(z) \tag{13},$$

$$\rho_2 = MJ_0(z) - \frac{M}{z}J_1(z) = -MJ_0''(z) \tag{14},$$

$$\rho_3 = J_0\left(\frac{4\pi(r+\beta)}{\lambda}\right) + \left(\frac{\beta}{\pi(r+\beta)} - \frac{24\beta^2}{(r+\beta)^2}\right)J_2\left(\frac{4\pi(r+\beta)}{\lambda}\right) + \frac{30\beta^2\lambda}{\pi(r+\beta)^3}J_3\left(\frac{4\pi(r+\beta)}{\lambda}\right), \tag{15}$$

and

$$\gamma = \frac{4\pi\alpha}{\lambda} - \tan^{-1}\frac{\rho_2}{\rho_1}. \tag{16}$$

$J_1(z)$, $J_2(z)$, and $J_3(z)$ are Bessel functions of the first, second, and third order.

(11) and (12) involve the approximation that higher powers of M and N than the second are negligible. Higher approximations do not alter the form of (11) and (12).

A comparison of (9) and (11) shows that one effect of the first overtone is to alter the position of the maxima. Thus the maxima of I_0 and I either coincide or are out of step by π radians while those of I_0 and I_1 are out of step by the angle γ. For the particular case in which $z=2.4$ and $\alpha=\lambda/20$, $\gamma=95°$. Consequently the first overtone should be seen when its amplitude is but one twentieth of the wave length of light employed.

A comparison of (9) and (12) indicates that similar to the effect the fundamental alone and in direct contrast to that of the first overtone, the effect of the second overtone is to introduce a fringe shift of either 0 or π radians. The presence of the second overtone is therefore difficult to ascertain by eye. It is interesting to note that when β/r is small, ρ_3 reduces to $J_0(4\pi(r+\beta)/\lambda)$ so that the fringes vanish at a value of r which is smaller than in the case equation (9).

APPARATUS

The quartz plates were examined in the range 100–2700 meters by coupling them directly across the variable condenser of a Hartley oscil-

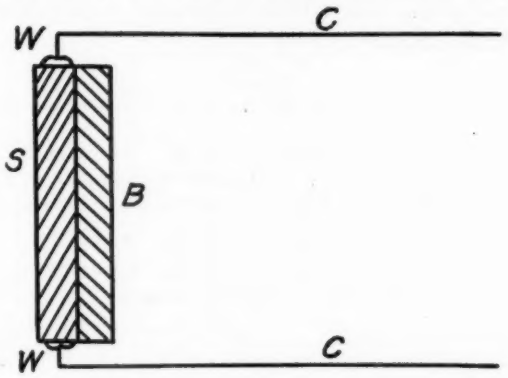


FIG. 4

lator activated either by two Cunningham CX-310 tubes in parallel or by a Radiotron UV-203-A operated on a plate source of 1000 volts.

The use of the silver coat as electrodes was adopted after a comparison had been made of the patterns and amplitudes secured by using as the electrode both transparent gauzes and silver coats of varying thickness. The thickness of the silver coat affected only the amplitude to a slight extent. These coatings were found to diminish greatly the danger of cracking the crystal when high voltages were applied.

The type of mounting is illustrated by Fig. 4. The crystal whose plane polished and silvered reflecting surface is S was supported by CC at knife edges which were forced into paraffin at W and W and then released to leave the crystal quite free. The support CC was fixed to one arm of a Michelson interferometer. Electric contact was made with S by a light spring tipped with gold foil (this gold foil can be seen in the upper

right-hand corner of the photographs) and at the opposite surface through the brass block *B*. A General Radio Precision Wavemeter, Type 224, Serial No. 12, served to determine the frequency of the Hartley oscillator. The reading of a Weston Thermo-ammeter, occasionally checked against dc and connected in series with the calibrated condenser across which was coupled the crystal, determined the applied crystal voltage. Whenever specific mention is not made to the contrary, the interferometer was illuminated by the 5461A line of mercury.

In Table 2 the description of the crystal cuts and dimensions are given in accordance with the terminology suggested by W. G. Cady.[10]

The orientation of the optic axis in crystals I, II, and IV has been determined optically by A. N. Winchell and found to lie within two degrees of the given directions.

TABLE 2.

Crystal	Cut	x in mm	y in mm	z in mm	Direction of electric field
I	*X*	4.32	22.46	25.24	*X*
II	*X*	4.32	22.47	25.77	*X*
III	*X*	4.655	23.30	25.44	*X*
IV	*Y*	27.65	2.325	20.65	*Y*
		Dimensions of IV given by Skellett are			
		27.1	2.44	20.8	

Crystal IV has been generously given to the writer by A. M. Skellett after having been examined by the glow method.[11] It should be observed that the orientation of the optic axis as determined optically by A. N. Winchell is at 90° with that determined from the glow patterns. The necessity of plane polishing reduced somewhat the y dimension given by A. M. Skellett. Since the x and z dimensions vary 0.3 mm from end to end, the tabulated value is the average in each case.

In the case of crystal II, one corner, as indicated by the photographs, had been ground.

AMPLITUDE OF OSCILLATION

The included photographs describe the variation in the amplitude of oscillation over the major crystal surfaces. In general, this amplitude is less than $\lambda/2$, though in the case of crystal III 1.2λ has been observed. Curves indicating the manner in which the amplitude varies with the

[10] W. G. Cady, Proceedings of the Institute of Radio Engineers *18*, 2136; 1930.
[11] A. M. Skellett, J.O.S.A. *17*, 308; 1928.

applied alternating crystal voltage have been presented in the advance publication.[3]

In the measurements made with a traveling cross hair upon the fringe shifts, these shifts were invariably half a fringe. The amplitude of the first overtone was therefore too small to be detected. This observation is in agreement with the results expected from the general theory of small vibrations.

PATTERN ANALYSIS

The frequencies of longitudinal vibrations have been calculated from the relations

$$f_1 = \frac{6240}{l} \tag{17}$$

and

$$f_2 = \frac{5430}{l}, \tag{18}$$

in which f_1 and f_2 appear in kilocycles/sec when the wave length, l, is measured in millimeters and in which 6240 and 5430 correspond to the velocity of a longitudinal wave calculated from Young's modulus along and at right angles to the optic axis respectively.

It has been proposed that the term "X-waves," "Y-waves," or "Z-waves" be applied to waves of whatever type whose direction of propagation is parallel to the X, Y, or Z axis respectively[10] (see Fig. 5). In the following, flexural or longitudinal waves propagated in the X direction are called "flexural X-waves" or "longitudinal X-waves" respectively. Similarly, flexural or longitudinal waves propagated in the Y direction are called "flexural Y-waves" or longitudinal Y-waves," and flexural or longitudinal waves propagated in the Z direction are called "flexural Z-waves" or longitudinal Z-waves." For brevity in listing and describing the observed patterns, it is convenient to denote by "$n(FX)$," "$n(FY)$," "$n(FZ)$" the calculated frequency, n, of flexural X, Y, or Z-waves respectively. Similarly, "$n(LX)$," "$n(LY)$," "$n(LZ)$" denote the calculated frequency of longitudinal X, Y, or Z-waves respectively.

$n(FY)$ in an X-cut and $n(FX)$ in a Y-cut have been determined from the relation given by H. Doerffler,[12]

$$f_3 = \frac{V_{\text{flexural}}}{l} = \frac{\sqrt{\sigma} V_{\text{transverse}}}{l} \tag{19}$$

[12] H. Doerffler, ZS für Physik *63*, 30; 1930.

in which the value of σ corresponding to a given wave length, l, was obtained from a table by Doerffler and the value of V transverse was taken to be 3840 meters/sec. The frequencies computed and observed by H. Doerffler apply to $n(FY)$ in an X-cut. But equation (19) may be expected to hold with equal accuracy for flexural X-waves in a Y-cut, since for both $n(FY)$ in an X-cut and $n(FX)$ in a Y-cut the controlling Young's modulii lie in the XY plane, where these modulii are equal, and since the controlling torsion modulii are in the direction of z. This is experimentally confirmed in the case of crystal IV.

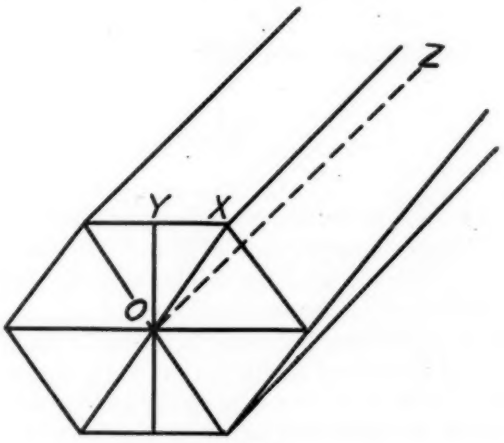


FIG. 5

The frequency $n(FZ)$ in the X and Y-cuts were calculated from the formula

$$f_4 = \frac{\pi}{4\sqrt{3}}\left(k - \frac{1}{2}\right)^2 \frac{d}{L}\sqrt{\frac{E}{\rho}},^{12} \tag{20}$$

where k is the number of nodes, d and L are either x and z or y and z according as the crystal is of the X or Y-cut, ρ is the density of quartz, and E is Young's modulus for the z-direction.

Table 3 affords a comparison of the calculated and observed frequencies. In the first column, pattern (1) of crystal I is denoted, for example, by $I(1)$. The computed frequencies which are in close agreement with the observed, n, are marked by an asterisk. This agreement is the criterion for determining the mode of vibration. All frequencies are given in kilocycles/sec.

The appearance of a large number of patterns in the high frequency region and few patterns in the low frequency region is common to every crystal. At high frequency, patterns may occur so often that, for example, in the case of crystal IV there is a considerable range of frequency over which the crystal oscillates continuously. Within this range the persistence of some patterns, once aroused, is remarkable. To illustrate, two patterns A and B oscillate most vigorously at frequencies a and b respectively. If A is first aroused, it may continue to oscillate beyond

TABLE 3.

Pattern	Description of pattern	n	$n(FX)$	$n(FY)$	$n(FZ)$	$n(LX)$	$n(LY)$	$n(LZ)$
I (19 & 23)	Checkerboard of Y and Z-waves	384		382*	388*		730	732
I (22)	Checkerboard of waves almost along Y and Z	426					855	850
I (18)	Checkerboard of waves almost along Y and Z	564					962	1010
I (13)	Broken set of Y-waves	621		587			1030	
I (1)	Broken Y-waves	688		330			697*	
I (4)		690						
II (28)	Set of diagonal waves	370						
II (22)	Set of diagonal waves	421						
I (26)	Broken Z-waves	397			720			757
II (16)	Checkerboard of Y and Z-waves	485		473	1040		857	884
III (2)	Broken Y-waves	582		453			817	
IV (4)	Broken X-waves	349	334			793		
IV (1)	Set of X-waves	473	472*			1010		
IV (3)	Broken X-waves	485	472			1010		
IV (24)	Broken X-waves	502	497*			1040		
IV (23)	Broken X-waves	703	738			1390		
IV (22)	Broken X-waves	717	738			1390		
IV (21)	Broken Z-waves	732			1445			1331
IV (18)	Diagonally crossed wave fronts	792						
IV (15)	Broken X-waves	826	850			1642		
IV (14)	X-waves broken by two sets of Z-waves	826	812			1495		
IV (13)	Broken X-waves	827	844			1540		
IV (10)	Broken X-waves	896	830			1520		
IV (8)	Broken X-waves	840	830			1520		
IV (6)	Broken X-waves	846	845*			1542		
IV (2)	Checkerboard of X and Z-waves	557	565*		899	1140		1190

the frequency b. With further change of frequency in the same direction A disappears but B cannot be made to appear. When the frequency is now changed toward the value b, B is first aroused and persists beyond

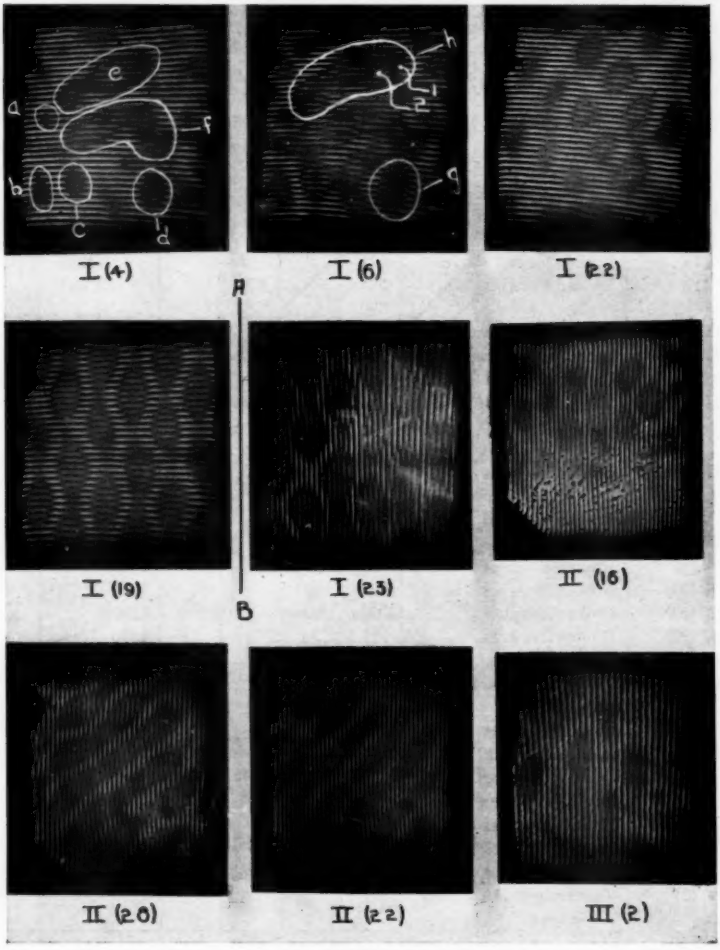


FIG. 6.

a, pattern A not appearing. This behavior is suggestive of the coupling of mechanical modes described by F. R. Lack.[13] The patterns in the low frequency region are invariably simple and regular.

[13] F. R. Lack, Proceedings of the Institute of Radio Engineers *17*, 1123; 1929.

$I(4)$ is characteristic of the large number of irregular patterns in crystals I, II, and III. Corresponding spots on front and back surfaces

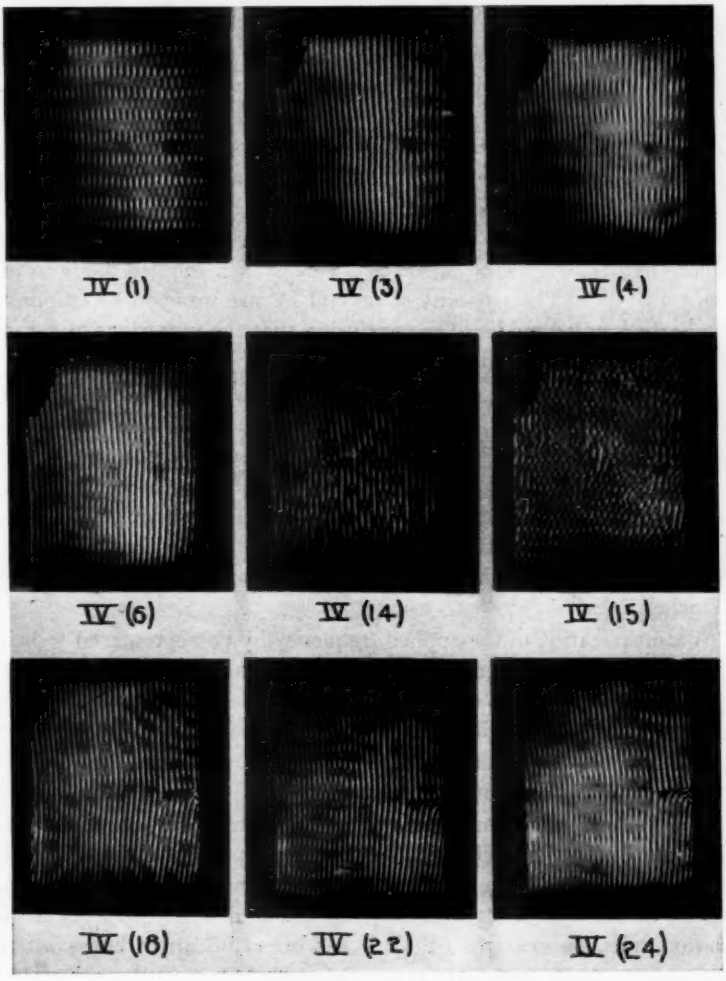


FIG. 7.

are found to differ greatly in appearance, but it is possible to recognize a similar set of broken wave fronts for both surfaces. $I(19)$ and $I(23)$ (see photographs) are characteristic examples from the front and back

surfaces in the case of a regular pattern and illustrate the close resemblance of corresponding spots, which are here located symmetrically with respect to AB. The agreement of the observed and calculated frequencies is, as would be expected, most frequent in the regular patterns.

Table 3 indicates that $I(19)$, $IV(1)$, $IV(2)$, $IV(6)$, and $IV(24)$ are flexural. Confirmation of the theoretical and experimental results relating to the frequency dependence of the velocity of flexural Y-waves in an X-cut published by H. Doerffler, and of the applicability of these results to X-waves in a Y-cut is found in the numerous agreements of calculated and observed flexural frequencies.

From $IV(1)$ and $IV(3)$ it appears that the mechanical vibration whose natural frequency is 472 KC enters as a coupled mode to produce 485 KC. The patterns of crystal IV are grouped to emphasize similarly coupled modes. The conclusion that the vibrations of a Y-cut are predominantly flexural is well supported.

The report by A. M. Skellett, who had previously examined crystal IV by the glow method, of a number of longitudinal waves is of interest here. Since the reduction in crystal thickness necessitated by plane polishing is slight, this frequent appearance of longitudinal waves appears to be due to the difference in the method of excitation. However, the direction of the optic axis as determined from the glow patterns by A. M. Skellett is at right angles to that determined optically by A. N. Winchell.

A multiplication of the applied frequency by two is required to bring this frequency into agreement with the calculated longitudinal frequency. $I(22)$, $IV(15)$, and $IV(23)$ are examples, $I(22)$ being the most interesting. $I(1)$ is longitudinal. Unless the peculiar property of an electrical frequency n to induce mechanical frequencies $2n$ is possible, $I(1)$ is the only observed longitudinal pattern.

If $I(19)$ is flexural, antinodes with the nearest node somewhat less than one quarter wave length removed are expected at the essentially free crystal edges. Photographs $I(19)$ or $I(23)$ reveal that the nodes are almost at the crystal edges. An explanation seems difficult. In the other photographs, for example $IV(1)$, it has been difficult to bring out the antinodes actually found at the crystal edges.

Attempts to excite separately the flexural modes of $I(19)$ by methods similar to those used by J. R. Harrison[14] and Doerffler failed.

A group of patterns consisting of wave fronts parallel to a crystal

[14] J. R. Harrison, Proceedings of the Institute of Radio Engineers *15*, 1040; 1927.

diagonal are illustrated by photographs *II*(22), *II*(28), and *IV*(18). Taking into account the mechanism of reflection at the crystal edges, it is difficult to explain how *II*(22) and *II*(28) can be produced as a longitudinal disturbance. Moreover, a calculation of the velocity from the relation $v=nl$ gives 1070 meters/sec and 1090 meters/sec in the case of *II*(28) and *II*(22) respectively. Since, also, the velocity of flexural waves increase with frequency, it is concluded that these patterns are flexural. These flexural velocities are strikingly lower than the ordinary and suggest an examination of these vibrations for low frequency control.

From examples such as the diagonal pattern in the preceding paragraph it is clear that a method of distinguishing between the longitudinal and flexural modes of vibrations will be of great service in the study of these vibrations. Accordingly, a triple interferometer arrangement is, at present, under construction in which the following are to be used as the two returning mirrors: (1) the front and back surfaces of the quartz plate; (2) the front surface and an auxiliary mirror; (3) the back surface and an auxiliary mirror. In arrangement (1) flexural patterns cause greater fringe disturbances than in either (2) or (3). On the other hand, longitudinal patterns cause smaller fringe disturbances in (1) than in (2) or (3).

The writer thanks Drs. J. R. Roebuck and H. W. March for their generous cooperation in the research here reported.

Spectroskopie Der Roentgenstrahlen. By Manne Siegbahn, University of Upsala. Second revised edition, 1931. 575 pp, 255 figures, 229 tables, 47 RM, bound 49.60 RM, Julius Springer.

The first edition of this work was a classic. The new edition which has been extensively rewritten and greatly enlarged is immeasurably superior. One scarcely realizes the developments which have occurred since 1923, the date of the earlier edition, until they are set forth as in the present volume. The book is divided into 8 chapters with a series of appendices. Following a six page introductory chapter dealing with early developments, Chapter II is devoted to a discussion of the optics of x-rays and general theoretical relations. Chapter III, embracing nearly 80 pages, discusses the technique of x-ray spectroscopy. Chapter IV in about 100 pages summarizes the data on emission spectra and Chapter V contains similar material for absorption spectra. Chapter VI devotes some 80 pages to the theory of x-ray spectra and correlations, energy levels, doublets, intensity rules, line breadths, spectra from multiply-ionized atoms, fine structure, etc. In Chapter VII the recent work in extending x-ray spectra to the optical region is treated with considerable detail under subjects such as line grating measurements, magnetic spectra of secondary electrons, absorption discontinuities in the ultraviolet, and critical potentials. Chapter VIII is devoted to theoretical and experimental work on the continuous spectrum. The appendices are mainly numerical data such as absorption coefficients, intense lines of various elements arranged according to wave length, data on reflection angle and wave length for various crystals.

The book is beautifully illustrated and contains numerous reproductions of typical spectra. On pages 488 to 560 is a summary of the literature, practically complete through the year 1930 with 61 references for 1931. The author and publishers are to be congratulated for such a timely treatise.

PAUL D. FOOTE

Opticks, or a Treatise on the Reflections, Refractions, Inflections, and Colours of Light. By Sir Isaac Newton. Pp. xxx+414. Reprinted 1931 with introduction by Professor E. T. Whittaker and foreword by Professor Albert Einstein. Whittlesey House, McGraw-Hill Book Company. $2.50.

This reprint of the fourth edition of Newton's *Opticks* (1730) carries a foreword by Einstein and an introduction by Whittaker that give the reader a setting for the book. Once a start on the text has been made the reader is kept eager by the interesting English forms and technical terms of two hundred years ago and by the author's careful descriptions and analyses.

Book I, on the Properties of Light, presents the author's experiments and propositions on refraction. Here are included a discussion of the law of refraction, the experiments on dispersion with single and crossed prisms, the proof that homogeneous light cannot be further dispersed, and the recognition of the nature of chromatic aberration in telescope lenses.

In the section on color Newton concludes that the color is inherent in the light, i.e., is not impressed on it by reflections or refractions. He gives here his account of the mixing of spectral colors to produce a match (in sensation, not in constitution) for any color, pure or compound. The rainbow is explained, and recognition indicated of the fact that certain bodies owe their color to selective transmission.

Book II deals with the colors of thin films, and gives detailed description of the colors of the rings seen when an air film between a plane and a spherical surface is used. The recurrence of colors in such a film indicates to Newton the regular recurrence of "fits of easy reflection and of easy refraction," and he determines the "interval of reflection," i.e., the increment of film thickness that causes a recurrence of a certain color. His value of this quantity for "the Rays which paint the Colour in the Confine of yellow and orange," interpreted in terms of the wave theory, gives .570μ for the wave length.

Less familiar to the casual student of optics is the attempt to explain the permanent color of natural objects (now often called body color) by means of the thin film effect and the proposal to estimate the size of particles of a body as that necessary to give the observed color in a thin film.

Book III presents certain conclusions of Newton not so often offered to the present day student, who usually hears that Newton rejected the wave theory because it would call for penetration of light into a shadow, and who infers that diffraction effects had not then been observed. Under Inflexions, Newton describes the effects observable with fine hairs, knife edges, and narrow slits, though of course his explanation is not that of today. He thinks of light as being bent away from the edge of an obstacle by some action of the matter on the light ray. He knew that the fringes with red light were farther apart than those with blue light. But though he suggests that the incidence of light may cause vibration in the object struck, especially the retina, and that sensation may result from the transmission of this vibration along the nerve substance; that some "subtile medium" may pervade a vacuum and all space; that sensation may be possible because this medium pervades the nerves; yet the idea of the transmission by this aether of force or motion is rejected, after careful consideration, because the corpuscular theory seems best to fit his interpretation of his known observations as a whole.

The book closes with thirty-one queries which touch natural philosophy from the constitution of matter through to what this philosophy reveals to

us of "our duty towards . . . the first Cause." Here the student of philosophy will find the delight that the student of optics finds throughout the book. The reader, whatever his interest, may well note the clear statement (p. 404) of the fundamental method of the scientist, and he will feel at the end the wish that he might emulate the great Newton in reverent openmindedness.

HARLEY HOWE

Seeing, A Partnership of Lighting and Vision. By M. Luckiesch, D. Sc., Director, Lighting Research Laboratory, General Electric Company, Nela Park, Cleveland, and Frank K. Moss, E. E., Lighting Research Laboratory. VII—241 pages, 26 page supplement plates, illustrations and tables. The Williams and Wilkins Company, Baltimore, 1931. Price $5.00.

The general purpose of this treatise is perhaps well brought out by the following scattered quotations from the authors; "Seeing, a partnership of lighting and vision—sharpen the visual tools, the eyes, with proper lenses and then give attention to adequate lighting—fatigue, mental and physical, through poor seeing has been given inadequate attention—eyes perfected throughout eons of evolution under thousands of foot candles of daylight illumination are subjected to severe visual tasks under intensities from 1/100 to 1/1000 of the original environmental intensity."

Statistics show that subnormal vision is preponderatingly prevalent among those engaged in eyestraining indoor work. Experimental results are presented by the authors to show how various factors affect seeing, i.e., visual acuity as a function of illumination, background contrast, and other factors; speed of seeing as a function of these factors. The effect of glare, defined as the "undesirable effect produced by light entering the eye directly from other than the object to be seen—usually an unnecessary by-product of lighting which may be eliminated or greatly reduced," is considered and experimental results presented. In fact all phases of the subject of "seeing" are discussed and experimental results are presented.

The authors point out that quantitative experimental evidence is difficult to obtain in short periods of time because of the enormous range of adaptability of the eye. However their ingenious tests show beyond doubt the validity of their conclusions.

This treatise will be helpful to anyone interested in conservation of vision; to anyone confronted with lighting problems or concerned with efficiency and productiveness in the work-world.

R. D. WYCKOFF